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EXPERIMENTAL CRYOPHYSICS

Sec 7.9 Taconis Oscillations

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and robustness of response

Perhaps the simplest among widely used level indicators is one based on the observation that when the cold end of a tube containing an oscillating gas column (see the next section) passes from the vapour into the liquid, the frequency of oscillation decreases by about 30 per cent, and the intensity of the oscillation decreases by about 60 per cent (Gaffney and Clement, 1955). *Figure 7.8.[11]* indicates the construction of the device.

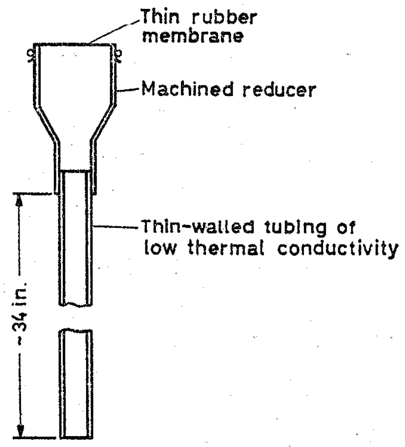

Figure 7.8.[11]. Liquid level finder (Gaffney and Clement, 1955)
(By courtesy of the Editor, *Review of Scientific Instruments*)

Inconel (or German silver) tubing, $\frac{3}{32}$ in. O.D., 0·008 in. wall, has been found to work well. If a tube of much smaller diameter is used, air may freeze inside the tube and stop the oscillations. If tubes of much larger diameter are used, the oscillations may become so intense that the liquid level is disturbed, the level thus becoming uncertain. Small sections cut from surgical gloves make rugged and sufficiently sensitive membranes; they should be about 1 in. in diameter. The liquid level, either hydrogen or helium, is found by holding the thumb or forefinger over the rubber membrane and noting the point at which an abrupt frequency-intensity change occurs. With care, helium levels can be measured to within 1 mm by this technique.

In a consideration of methods of liquid level determination, the following very simple procedures should not be overlooked. The contents of storage containers of liquid oxygen, air and nitrogen, which are appreciably denser than liquid hydrogen and helium, are frequently followed by simply weighing the container and its contents. A technique applicable to all liquids is to use slit-silvered Dewar vessels which permit direct viewing of the liquid level.

7.9. THERMAL OSCILLATIONS

It has long been recognized that the gas in a tube, the closed end of which is hot and the open end of which is cool, can go into spontaneous oscillation. In fact, in Lord Rayleigh's classic work, *The Theory of Sound*, reference is made to the observation of this phenomenon by glass blowers and a physical picture is given for the mechanism of these oscillations. In low temperature apparatus, conditions for such oscillations are frequently present. While they always add heat to the low temperature portions of the apparatus and are therefore undesirable, there is at least one reported instance when such oscillations were used to good effect, namely, to stir liquid and vapour in experiments in which the ^{3}He/^{4}He equilibrium ratios in the two phases were being determined (Taconis, Beenakker, Nier and Aldrich, 1949).

Keesom (1942) has commented on the Leiden experience in this connection; the heat transport effect for liquid helium was noted as was the fact that this phenomenon interfered with measurements of the ratio of specific heats at liquid hydrogen temperatures. It has been observed that spontaneous oscillations can increase the evaporation rate of storage containers by a factor of one thousand (Wexler, 1951). Squire (1953) has commented on some of the properties of these oscillations. More recent work (Clement and Gaffney, 1955), prompted by difficulties in using a particular transfer tube, reported additional descriptive observations; this work has led to the simple level finder described above.

While both a qualitative description of the mechanism of thermal oscillations in low temperature apparatus has been given and a quantitive treatment attempted (Kramers, 1949), the physical picture remains essentially that given by Rayleigh. Consider a tube closed at the room temperature end, open at the low temperature end and terminating in either the vapour or liquid phase. It may be assumed from the geometry that the tube is a quarter-wave resonant tube with a pressure node at the cold, open end and a pressure antinode at the hot, closed end. During the compression phase, the motion of gas is towards the closed, hot end of the tube. The gas undergoing compression and moving towards the hot end heats because of the work being done on it. If the temperature gradient is sufficiently steep along the wall of the tube, the heated gas will find itself in contact with a section of wall at a still higher temperature, so that heat will flow into the gas, thereby increasing the pressure and energy content further. During the expansion phase, the reverse process occurs, the gas rejecting heat to the wall at low temperature.

This process may be visualized (Garfunkel, 1957) by referring to *Figure 7.9.[12]*, wherein are plotted pressure–volume adiabatics for an element of mass of the gas undergoing oscillation. Two cases are considered. In *Figure 7.9.[12]b* the temperature gradient is steep enough for the heat exchange of the gas with the wall to reinforce both the expansions and contractions of the gas. The *P–V* loop will expand until dissipation of energy external to the gas, e.g. by sound radiation, is just equal to the area of the loop. If the temperature gradient is not steep enough, the *P–V* loop tends to collapse as the result of the heat exchange between the gas and the wall as shown in *Figure 7.9.[12]a*. From the figures it is clear that in addition to an appropriate temperature gradient, the thermal contact between the gas and the wall must be neither too good, in which case a single line would be traced out on the *P–V* diagram, nor too poor, in which case insufficient heat will pass between the gas and the tube. This explains the observation

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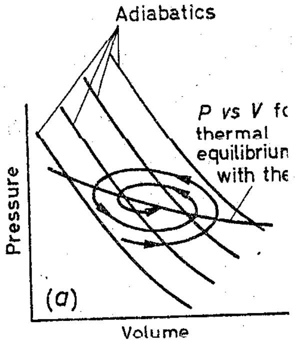

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7.10. FABRICATION TE

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(Clement and Gaffney, 1955) that thermal oscillations are restricted to a range of tube diameters. When a cavity is added at the closed end it is observed that at first the intensity of the oscillations increases and then decreases as the volume of the cavity increases. This can be explained by noting that the initial increase in volume permits larger displacements of gas at the hot end. As the volume increases, however, this end approaches the characteristics of an open end, thereby changing the mode of vibration in the tube to one unfavourable for sustained oscillations. Again the foregoing makes plausible the efficacy of closing the low temperature end of a tube in minimizing the strength of the thermal oscillations (Squire, 1953; Clement and Gaffney, 1955).

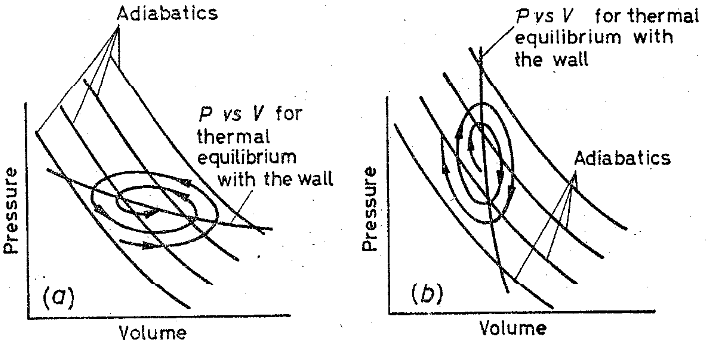

Figure 7.9.[12]. Representation of thermal oscillations in the P–V plane: (a) *temperature gradient too small to sustain thermal oscillations;* (b) *temperature gradient sufficient to sustain thermal oscillations*

7.10. FABRICATION TECHNIQUES FOR METAL VESSELS

While fabrication techniques for metal Dewar vessels vary considerably, depending on their application, many of the techniques used may be illustrated by outlining the procedure used in the fabrication of a container like that shown in *Figure 7.4.*[*6*]*b*. The first step consists of soft soldering a low conductivity neck tube, of stainless steel or inconel, to the upper copper spinning of what will become the inner sphere. The spinnings vary in thickness from about $\frac{1}{32}$ in. for containers of 5–10-l. capacity to $\frac{1}{16}$ in. for containers of 100-l. capacity. Solder fillets are run in on both the upper and under sections of the joint between the spinning and the neck tube. Next the inner sphere is completed by soldering the lower half of the sphere to the upper one. These are arranged to fit tightly in the absence of solder. Soldering is accomplished by pre-tinning the joining surfaces, running a neat filleted solder band around the joint, and then puddling a soft solder band around the joint. The outer surface of the inner sphere is washed free of spinning soap and dipped in a weak acid solution to remove the oxide. This surface, as well as the outer surface of the neck tube, is buffed on a wheel, and the surfaces are then hand polished with a fine

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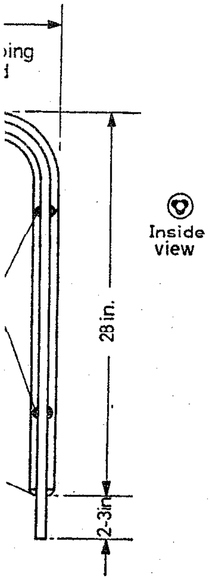

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a Dewar vessel or transfer tube goes soft, the vacuum space is flushed with dry nitrogen and the space is repumped.

7.11.6. GLASS-TO-METAL SEALS

Glass-to-metal seals are very useful in low temperature research. They simplify the assembly of apparatus, eliminate the necessity for having, in the warm regions of the vacuum system, fabric-covered wires which can desorb gas, and make it possible to cool lead wires directly in the refrigerant bath. Both tube and wire seals are required. A number of successful metal and glass combinations have been used (Corak and Wexler, 1953), including copper Housekeeper seals, zirconium-to-glass, and tungsten-to-glass. About Kovar-to-glass seals there is disagreement as to their usefulness, some investigators reporting excellent results (Lane, 1947) and others reporting unreliable results (Corak and Wexler, 1953). It is possible that the difference in experience reflects differences in performance of seals of this type depending upon the composition of the Kovar and of the sealing glass.

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8. MAG

8.1.

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8.2. THE THERMODY

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